Some peculiarities concerning the Pliocene evolution of the Black Sea and Caspian basins

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ABSTRACT

This paper presents the results of petromagnetic studies on Pliocene key sections of Crimea, Georgia, the Apscheron Peninsula and the North Cis-Caspian Region. Scalar magnetic characteristics of sedimentary rocks reflects the conditions they have been formed in the eastern Para-Tethys. The Pliocene activation is recorded by increased rock magnetism in the middle Pliocene. The dependence of petromagnetic variations upon tectonic factors allows to correlate the marine Pliocene succession from the Ponto-Caspian District.

KEY WORDS
Petromagnetism,
scalar magnetic characteristics,
magnetic susceptibility,
Para-Tethys,
Pliocene.

RÉSUMÉ

Quelques particularités de l'évolution pliocène des bassins de la Mer noire et de la Caspienne.

Cet article présente les résultats d'études pétromagnétiques des dépôts pliocènes de Crimée, de Géorgie, de la péninsule d'Apscheron et de la région nord de la Cis-Caspienne. Les caractéristiques magnétiques scalaires des roches sédimentaires reflètent les conditions dans lesquelles elles ont été formées dans la Para-Téthys orientale. L'activation pliocène est enregistrée par une augmentation du magnétisme au Pliocène moyen. La dépendance des variations pétromagnétiques vis à vis des facteurs tectoniques permet la corrélation des dépôts marins de la région Ponto-Caspienne.

MOTS CLÉS
Pétromagnétisme,
caractéristiques magnétiques scalaires,
susceptibilité magnétique,
Para-Téthys,
Pliocène.

INTRODUCTION

Tectonic activity of the Caucasus and adjacent mountain areas at the Miocene-Pliocene transition has speeded up the disintegration and final disappearance of the Para-Tethys Basin. The western Para-Tethys disappeared and the eastern Para-Tethys was ultimately disintegrated at the end of the early Pliocene, which resulted in the final isolation of the Pontic and Caspian seas (Nevesskaya *et al.* 1986).

Since their development proceeded practically independently, though occasional reunification through the system of latitudinal Kuma-Manych depressions was established. The geologic record of the Caspian water break-through into the Cis-Pontic Region at the end of the middle Actchagylian (the beginning of Matuyama epoch) is most clearly demonstrated by the beds with common mollusc fauna: Tamanian beds containing the Actchagylian *Cardium* in the Cis-Pontic Region and the Pontic *Dreissenia* within the Actchagylian of the Caspian Section (Kitovani 1976; Nevesskaya *et al.* 1986; Zubakov 1990).

The general evolution scheme of isolated Peri-Tethys basins was traditionally based on lithofacies and palaeontological data. Palaeomagnetic research, especially after Harland *et al.* (1982) magnetochronologic scale, provided the framework for more solid and precise correlations of geologic events in the Black Sea and Caspian regions. Recent research have demonstrated that most interesting stratigraphic, palaeogeographic and geochemical information is to be found in scalar magnetic characteristics of sedimentary rocks; the "magnetic memory" of these rocks reflects the main events of their formation in various geodynamic and landscape-climatic settings (Molostovsky 1986; Guzhikov & Molostovsky 1995).

The results of palaeo- and petromagnetic re search of the marine Pliocene and Pleistocene from the Kerch Peninsula, western Georgia and Apsheron Peninsula are presented (Fig. 1).

In this study beside palaeontological, palynological and lithologic-mineralogical data, a substantial amount of original and previously published palaeomagnetic data was used for palaeogeographic reconstructions (Ali-Zade 1954; Khramov 1963; Asadulaev & Pevzner 1973; Trubikhin 1977; Zubakov 1990). The authors gathered the material on scalar magnetic characteristics and add data from Ismail-Zade (1967) and Khramov (1963).

Magnetic susceptibilities were measured by IMV-2 and KT-5 devices, remanent magnetisation – by spinner-magnetometers ION-1, JR-3, JR-4.

The basic palaeomagnetic material used for comparative analyses is summarised in a correlation scheme showing with the Pliocene stratigraphic units from the Black Sea and Caspian regions in relation to the general magnetostratigraphic scale (Fig. 2).

MAIN PRINCIPLES OF STRATIGRAPHIC INTERPRETATIONS OF PETROMAGNETIC DATA

Petromagnetic variations of sedimentary sequences are controlled by the depositional processes and boundary conditions that determine the formation of these units. Therefore, a subdivision of stratified rocks based on common scalar magnetic characteristics, has sedimento-stratigraphic significance.

The sedimentary rock magnetic properties are determined by both natural (magnetic susceptibility – k, modulus of natural remanent magnetisation – Jn, etc.) and artificial parameters i.e. measured after exposure to temperature and/or a laboratory magnetic field (magnetic susceptibility of a sample after exposure to temperature – dk, saturation magnetisation – Js, saturation field – Hs, etc.).

The values of natural petromagnetic characteristics – magnetic susceptibility (k) and natural remanent magnetisation (NRM, Jn) – depend mostly on ferromagnetic mineral concentrations as well as on magnetic phase compositions, secondary changes and others. The Jn modulus is mainly controlled by the degree of order of domain magnetic moments, which results in higher Jn in chemically magnetised rocks than in those with orientational magnetisation, while magnetic susceptibility values do no vary. In weakly magnetised rocks (k = 10-20.10^{-5} SI

FIG. 1. — Location map. **I**, Great Caucasus; **II**, Adjar-Trialet mountain system; **III**, Balkhan; **IV**, Kopet-Dag; **V**, Talysh Mountains. Sections: **a**, wells 1, 5, 13, 14, 15, 18, 19 (Samara Region); **b**, well 3 (Saratov, Volga Region); **c**, well 20 (Saratov, Volga Region); **d**, well 13 (Kalmykia); e, well 48 (Kalmykia); **f**, Kerch Peninsula; **g**, western Georgia.

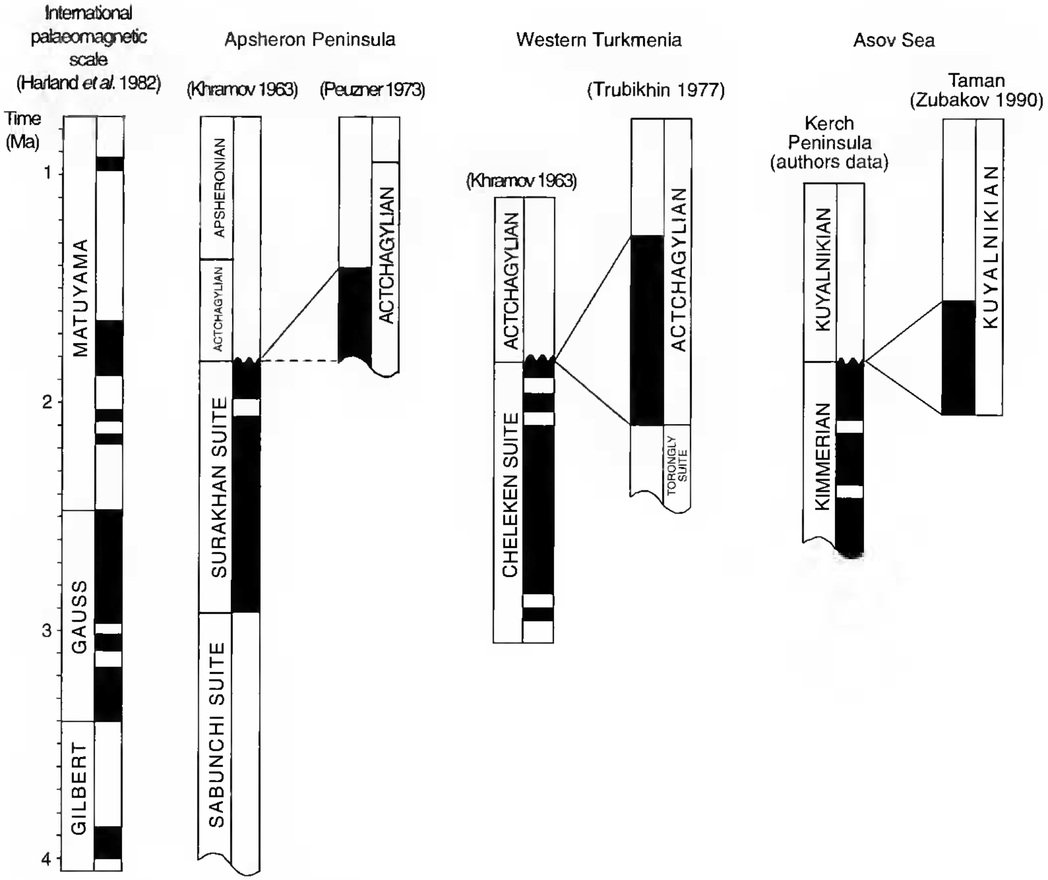

FIG. 2. — Correlation between palaeomagnetic sections of the Pliocene from eastern Para-Tethys.

units) paramagnetic components strongly affect k-value formation. All the petromagnetic indices are functionally associated with sediment composition, textural-structural rock features, palaeogeographic and geochemical sediment composition epigenetic changes, i.e., with all parameters controlling the formation of the large sedimentary complexes within concrete palaeobasins.

The obvious relationship between petromagnetism and sedimentation processes provides potentially a wide application of scalar magnetic characteristics in solving diverse geologic problems; the petromagnetic method can be considered as a form of rhythmostratigraphic analysis. Detailed knowledge of the ferromagnetic-fraction mineralogy forms the fundamental basis in the interpretation of such data.

A large amount of data on magnetic properties of sedimentary formations of diverse ages and genesis were summarised by the authors; this made it possible to formulate the main principles of palaeogeographic interpretation of petromagnetic indices. The essence of these principles accounts to:

1. Magnetic differentiation of rocks within a stratigraphic section is controlled by the changes in sedimentation environments.

In rocks with syn- or post-sedimentary magnetisation carried by allothigenic ferromagnetics, palaeogeographic and tectonic factors are definitive, i.e., those controlling terrigenous magnetic material erosion, transport deposition (tectonic activity, climatic changes affecting the rate of baring processes). The increased concentration of detritic ferromagnetics is registered by k and Jn bursts on petromagnetic curves.

In rocks with chemically introduced NRM contained by authigenic minerals, magnetic properties are controlled by the geochemical environment during the formation of the authigenic magnetic phase. For example, in reducing conditions due to some sulphur deficit, authigenic sulphide mineralisation is observed within the sediments with strongly magnetised pyrrhotine and greigite being formed together with pyrite. Variations in geochemical conditions may result in variation in different distribution of magnetic sulphides within a stratigraphic section, which is registered by changes in magnetic susceptibility and natural remanent magnetisation.

2. The levels of substantial changes in sedimentary sequence magnetism constitute the natural interfaces between real stratiform bodies, and the petromagnetic layer-sets themselves may be classified as stratigraphic units of local or regional importance.

3. Sediment petromagnetic differentiation in time is of regular character and reflects sedimentation peculiar and reflects changes in sedimentation processes and environment. Spasmodic petromagnetic changes generally coincide with sharp changes in sedimentation.

4. Petromagnetic rhythms within periods of erosion or non-deposition parallel sedimentation rhythms.

In case of detrital nature of Jn, the initial (regressive) stages of sedimentation cycles are marked by a drop in magnetisation. When magnetic rhythm is controlled by changes in palaeogeochemical conditions significant increases in Jn and k are observed in deep-water sediments, containing authigenic phases – pyrrhotine and greigite, which formed under the reducing conditions.

5. Petromagnetic variations, observed after heating of samples in laboratory, reflect concentration variations in originally non-magnetic or weakly magnetic ferriferous minerals (pyrite, marcasite, siderite, iron hydroxides). These minerals are clearly recorded magnetometrically after conversion under elevated temperature.

Pyrite and marcasite, for example, when heated up to 500 °C in oxidising medium, turn into magnetite, which results in magnetic susceptibility increase. The increase in $Dk = k_T$-k reflects the content of newly-formed magnetite, and thus, concentrations of initial FeS_2.

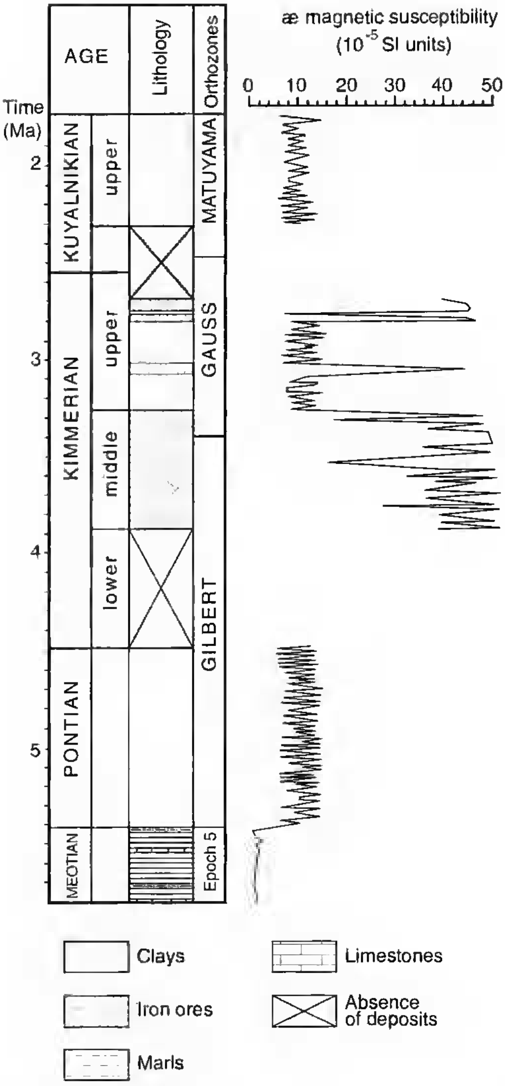

FIG. 3. — Synthetic petromagnetic curve of Pliocene deposits of the Kerch Peninsula.

If non-magnetic iron sulphides are of authigenic nature, the abnormally high increase of magnetic susceptibility mirrors the reducing environment in a sedimentary basin, with the presence of hydrogen sulphide; dk – curve variations form the basis for detailed sequence division and let yield constrain on the changes in redox potentials of sedimentation environment.

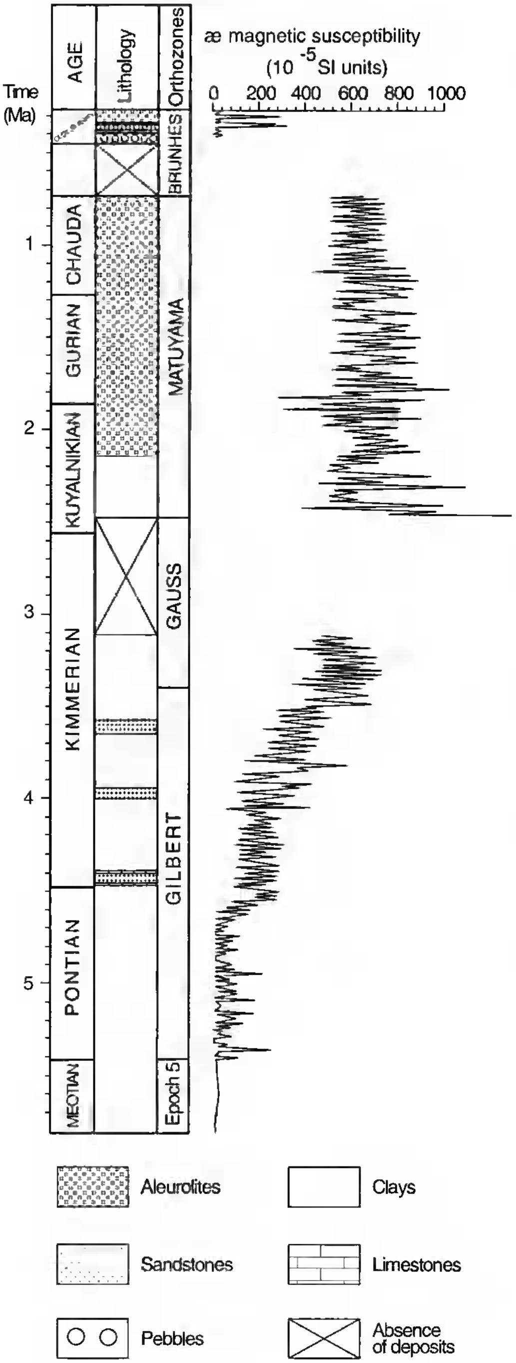

FIG. 4. — Synthetic petromagnetic curve of Pliocene and Pleistocene deposits of western Georgia.

INVESTIGATION RESULTS

KERCH PENINSULA

Reconstruction of palaeogeographic events on the basis of the palaeo- and petromagnetic data of the Black Sea Region, is possible from the end of the Miocene to the beginning of the Pliocene. The analyses of several composite sections through the Meotian and Pontian beds in Kerch Peninsula demonstrate that similar changes in magnetic properties can be observed in sediments from various parts of the basins.

Clayey-carbonate deposits of Meotian age in the north-western Cis-Pontic Region are ubiquitously distinguished for extremely low and homogeneous magnetisation. Their magnetic susceptibility varies between 3 and 8.10^{-5} SI units.

The beginning of the Pontian transgression in the large Euxinic Basin was accompanied by accumulation of dark-grey deep-water clays, dominating practically in all the sections from western Georgia and Kerch-Taman regions. The beginning of the Pliocene is everywhere marked by substantial changes in marine sediment petromagnetism.

Within the Pontian beds of Kerch Peninsula, the level of magnetisation is at least two times higher than in the Meotian terrigenous-carbonate sequence. Modal k values, here, are as high as 15.10^{-5} SI units (Fig. 3).

During the Kimmerian, deep-water clay accumulated. These clays contain intercalations of chemogenic siderite-leptochlorite ores in the middle part of the section which was deposited in the Kerch and Taman areas. The interlayers resulted from erosion and transport to the littoral zone of the local laterite crusts of weathering (Zubakov 1990).

The increased iron-salt contents in the middle Kimmerian sediments had relatively small influence upon their magnetic properties due to the absence of strong magnetic phases. Magnetic susceptibilities in iron ores are increased (20-55.10^{-5} SI units) relative to those of the host rocks ($k_{mod} = 12.10^{-5}$ SI units).

Break of erosion of the laterite-crust at the end of the Kimmerian is recorded by a marked magnetisation decrease in the rocks of the upper

Kimmerian and Kuyalnikian where the k values do not exceed 14.10^{-5} SI units (Fig. 3).

WESTERN GEORGIA

Petromagnetic differentiation in western Georgia is much more marked than in the north-western Cis-Pontic Region, in spite of the homogenous character of the section composed of grey deep-water clays, with some sandstones and aleurolites.

The Meotian/Pontian boundary is recorded as a clear change in petromagnetic response of the sequence (Fig. 4). In western Georgia, the Meotian clayey-aleurolitic sequence is also distinguished for low magnetisation: $k_{mod} = 20.10^{-5}$ SI units. Magnetic susceptibility values are significantly higher in the lower part of the Pontian section; they vary between $20\text{-}200.10^{-5}$ SI units. Sediment magnetisation increases steadily upwards along the section, and within the upper horizons of the Pontian, the k values vary between $k = 40\text{-}300.10^{-5}$ SI units.

Magnetic susceptibility values increase up to $200\text{-}800.10^{-5}$ SI units, in the Kimmerian, reaching the maximum in the clays and aleurolite of the Kuyalnik, Gurian and Chaudian horizons: $k = 300\text{-}1300.10^{-5}$ SI units ($k_{mod} = 660.10^{-5}$ SI units).

In the Pleistocene, the transport of terrigenous magnetic material decreased significantly, its input to the ancient Euxinic Basin was more episodic. This is marked by alternation of strongly and weakly-magnetised layers in the petromagnetic records. In weakly magnetised sediments the k values vary between 9 and 40.10^{-5} SI units, in strongly magnetic sediments $k = 80\text{-}320.10^{-5}$ SI units (Fig. 4).

Thick (up to 3500 m) Pliocene deposits with unique magnetic properties, were formed in western Georgia at the end of the Cainozoic. Judging from petromagnetic data, the processes of marine accumulation in this region were mainly controlled by intensive ascending movements of the western part of the Great Caucasus and Adjar-Trialet Mountain system. Their activity is usually correlated with the middle/late Pliocene transition (Kitovani 1976) but the petromagnetic record clearly indicates that tectonic activity started as early as the earliest Pliocene.

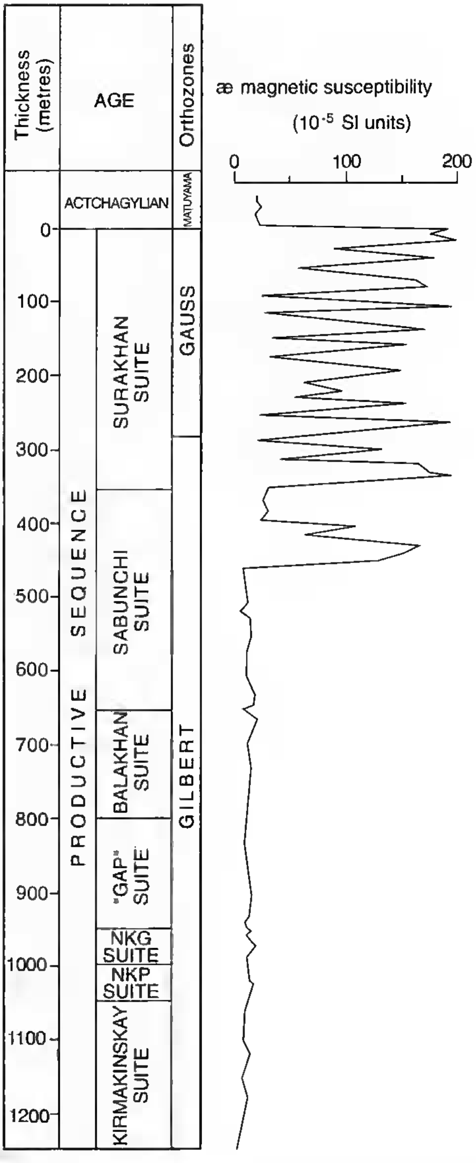

FIG. 5. — Synthetic petromagnetic curve of Pliocene deposits of the Apsheron Peninsula (Khramov 1963; Ismail-Zade *et al.* 1967).

Magnetic material was mainly provided by the Eocene volcanic covers, widely spread in the southern regions of Georgia. The erosion of highly-magnetic sequences in the mountains continued with increasing intensity right up to the end of the Pliocene. Baring rates seemed to have decreased in the Pleistocene, but the presence of magnetite-saturated beach sands in the vicinity of the towns of Poti, Ureki and Magnetiti (Guria) suggest that the process continue.

Petromagnetic section correlation with the magnetochronologic scale suggests that the Adjar-Trialet Mountain massif is the most active geodynamic centre of the Black Sea region for the last 5.4 Ma: intensive bating continues since the beginning of Gilbert epoch (Fig. 4).

The transgressive-regressive variations of the Euxinic Basin, contrary to the north-western Cis-Pontic, are not clearly reflected in the Georgian sections, though they are easily recognised from numerous unconformities within the Pliocene sequence. The most expressive trace was left by the Kimmerian activation, which resulted in strong reduction of Gauss zone in many sections.

CASPIAN REGION

No petromagnetic data on the lower Pliocene from the Caspian Region is available. In the middle Pliocene portion of the scale, the productive sequence from Apsheron Peninsula is relatively well studied, as well as its correlative red-bed (Cheleken) suite from western Turkmenia (Khramov 1963). These rock complexes were deposited in semi-freshwater basins with intensive terrigenous sedimentation; the basins originated in the Caspian Region during the Kimmerian transgression of the Euxinic Basin (Muratov & Nevesskaja 1986).

The Kimmerian tectonic event did not leave any notable traces in the petromagnetic section from the Trans-Caspian due to the lack of highly magnetic source rocks in the western Kopet-Dag and Balkhan. The redstones, aleurolites and clays of the Cheleken suite are generally characterised by moderate magnetisation (k = 15-25.10^{-5} SI units) and are poorly differentiated along the stratigraphic section (Khramov 1963).

The petromagnetic section through the productive sequence from Azerbaijan is more informative in this respect (Fig. 5). According to Khramov (1963) and Ismail-Zade *et al.* (1967) data, the lower part of this large terrigenous complex (~800 m) is composed of low-magnetised clays, aleurolites and sandstones with the average k va 13.10^{-5} SI units. In the upper part of the Sabunchi suite, a sharp magnetisation increase is observed in all rock varieties, accompanied by a substantial dispersion of scalar magnetic characteristics: k = 13-160.10^{-5} SI units (k_{mod} = 75. 10^{-5} SI units). A similar magnetisation level is characteristic of the overlying Surakhan suite; the overall thickness of the highly magnetic complex constitutes up to 450-500 m (Fig. 5).

The large volumes of magnetic material transported to the regressing Balakhan reservoir might have been caused by the increased tectonic activity of the eastern flank of the Great Caucasus or the Talysh Mountain massif in the southern Cis-Caspian. In any case, the intensive baring of Mesozoic and Palaeogene volcanite sequences of intermediate and basic composition, resulted in the accumulation of magnetic material in the upper horizons of the productive sequences.

The Pliocene activity in the eastern Caucasus is dated rather precisely by the magnetostratigraphic scale (Fig. 5) as the end of Gilbert epoch plus the early Gauss, which approximately corresponds to the interval of 1 Ma.

Correlations of regional magnetostratigraphic schemes and composite petromagnetic columns show, that notwithstanding the complete isolation of the Caspian and Euxinic basins in the middle Pliocene, the Kimmerian tectonic activation has similarly affected sedimentation throughout the whole of the eastern Para-Tethys.

In the north-western Cis-Pontic and Apsheron regions, this is marked by the clear enough petromagnetic effects in the sections through the middle Kimmerian (ore) and the Surakhan suite. In Kerch Peninsula, western Georgia, Azerbaijan and Turkmenia, an unconformity separates the upper horizons of the Kuyalnikian and Actchagylian from the Kimmerian super-ore sequence, Surakhan and Cheleken suites; the upper half of Gauss zone is not present in the section (Fig. 2).

All the authors analysing the Pliocene history of the Black Sea region, note the relative stability of the Euxinic configuration and its correspondence with the modern Black Sea area. It is only at individual stages of the eastern Para-Tethys evolution when large bays came into existence in the Kuban-Azov Region and Guria (Kitovani 1976; Nevesskaja *et al.* 1986).

The limited lateral amplitudes of the Euxinic

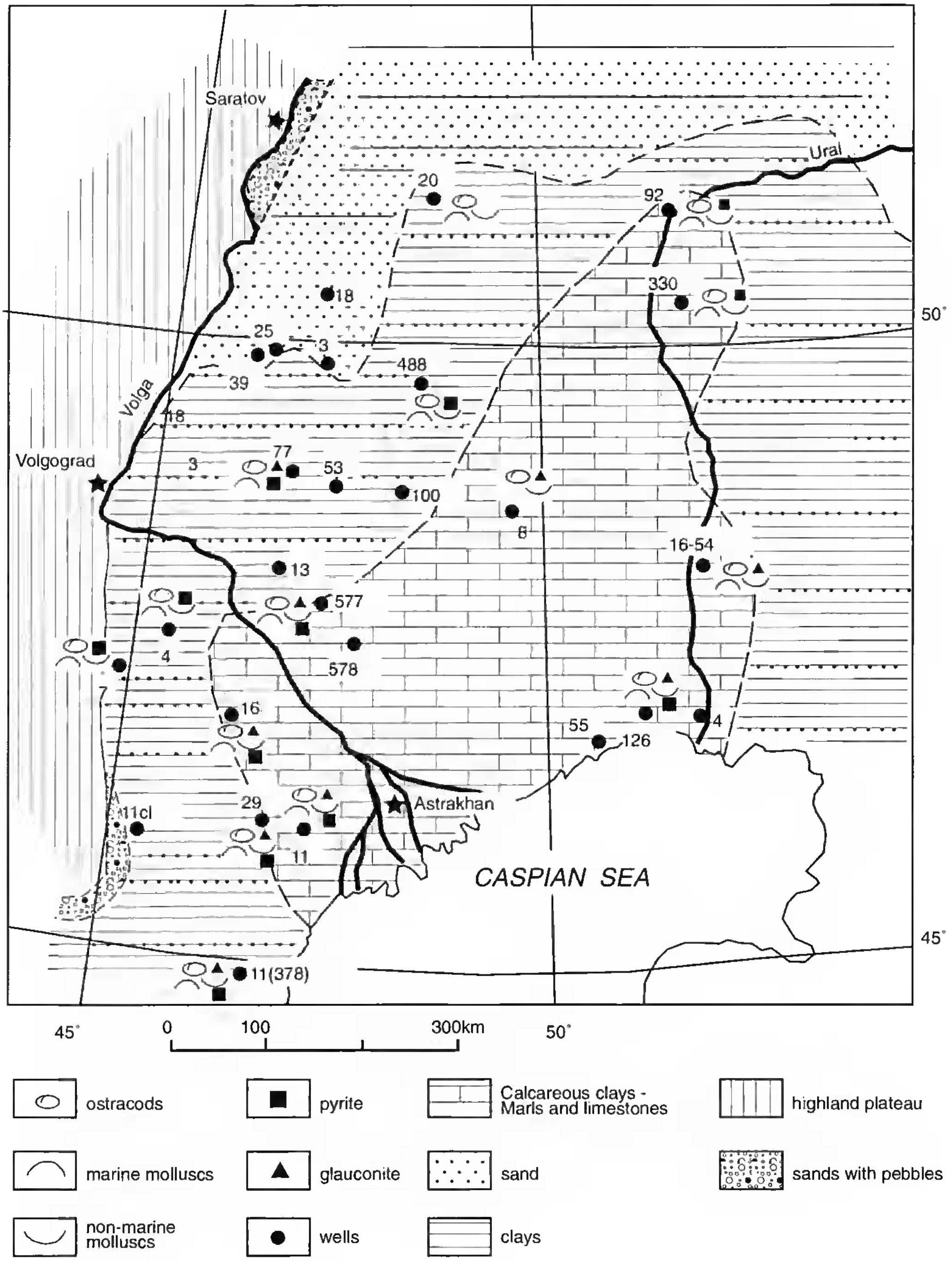

FIG. 6. — Lithological-palaeogeographical scheme of Actchagylian stage of the Caspian Depression (Akhlestina & Karmishina 1973).

transgressions with dominating plain savannah-steppe landscapes in the Cis-Pontic Region (Zubakov 1990) combined with the thick transgressive series indicate the tectonic quiescence in the region and limited erosion all over the northern fringe of the Euxinic.

It follows from Figure 3, that the Pliocene transgressions were accompanied by the changes in the magnetic properties of corresponding sediments. The amplitudes of petromagnetic variations themselves are insignificant, because only the upper, weakly magnetised horizons of the sedimentary cover have undergone erosion in the sourceland. The large volcanic massif of the Kara-Dag (southern Crimea) evidently did not serve as a source area for the northern Euxinic Basin in the Pliocene.

From palaeontological and lithofacies data, Kitovani (1976) concluded, that the Kuyalnikian age represented the turning point in modern history of the Black Sea region. It corresponds to the beginning of a major transgressive cycle that should be considered as the start of the late Pliocene.

This conclusion is supported by all data, but the basic importance of the Kuyalnikian (Actchagylian) stage for the evolution of the northern fringes of the Tethys is not limited to the Black Sea basins.

Palaeogeographic reconstructions show that the Neogene history of the Para-Tethys is characterised by alternating episodes of isolation and reunification of individual basins (Nevesskaya *et al.* 1986). All the geologic events of that period, accompanied by transgressions and regressions, occurred in the sublatitudinal direction between 40 and 50°N; the northern margin of the Peri-Tethys zone hardli ever crossed the conventional line between the present Volga Delta and the Taganrog Bay of the Azov Sea.

A fundamentally new geodynamic situation was formed at the beginning of the Actchagylian.

A number of large-scale transgressions have resulted in cardinal change of water-masses movement direction: from the sublatitudinal to the meridional one. A large brackish-water basin arised in the Caspian Region: it stretched from the southern shores of the modern Caspian Sea for more than 2000 km, right to the lower reaches of the Kama River. This basin, nearly equal in its area to the whole of the Para-Tethys, lasted through the Apsheronian and disintegrated only in the early Pleistocene due to a major Tjurkian regression.

Facies of the Upper Pliocene were studied in detail in a number of papers (Kolesnikov 1940; Ali-Zade 1954; Asadtlaev & Pevzner 1973; Trubichin 1977). Coarse-detrital sediments from 5-10 to 50-60 metres thick accumulated in littoral zones. Shallow-water sediments were deposited at moderate depths (down to 100 m); they are represented by alternating aleurolites and sandstones up to 400 m thick. Carbonates and deep-water clays with authigenic iron sulphides (pyrites and greigites) were deposited in the central parts of the reservoir under the conditions of hydrogen-sulphide contamination. Greigite is characterised by pronounced ferromagnetism and to a large extent determines the magnetic properties of the Pliocene marine deposits from the northern Cis-Caspian.

The facies variations of Actchagyl northern Cis-Caspian Basin are analysed by Akhlestina & Karmishina (1973) (Fig. 6).

The structures of the majority of the Cis-Caspian Pliocene sections studied in Kalmykia (well 13), Satatov Region (wells 3, 20), clearly reveal sedimentation rhythms, caused by alternating transgressive and regressive cycles. Each sedimentation rhythm comprises arenaceous (regressive) and argillaceous (transgressive) members with the average thickness as of 30-50 m. Judging from the data published, such a structure of the Pliocene sequence is common for the whole of the Volga and northern Cis-Caspian regions. Mineralogical analyses have established that the authigenic minerals pyrite-greigite association characterise the transgressive series, while siderite and iron hydroxides are characteristic of the regressive ones. Transgressive-regressive sedimentation phases in petromagnetic columns are registered by strong variations of scalar magnetic characteristics. In the transgressive portions of the elemental rhythms, Jn and k values vary, basically, within the ranges of $20\text{-}150.10^{-3}$ A/m and $100\text{-}500.10^{-5}$ SI units. In the regressive (arenaceous) facies, they decrease to $0.5\text{-}10.10^{-3}$ A/m and $10\text{-}30.10^{-5}$-SI units.

In some sections, composed of lithologically homogeneous sequences or closely interlayered rocks, magnetic parametrics becomes a more precise indicator of environmental changes in the deeper parts of the basin, than the traditional litho-facies methods.

The available data do not allow the establishment of the total number of elemental sedimentation rhythms within the Cis-Caspian Actchagylian-Apsheronian sequence, since this number may vary with the section completeness and sedimentation conditions.

The comparative analyses of petromagnetic data from wells 13 and 48 have revealed a quite clear correlation between the compositions of spore-pollen complexes and rock magnetisation. Highly magnetic transgressive portions of the rhythms are generally associated with the complexes of forest-steppe and forest types with the content of arboreal pollen as high as 50-65% and that of herbaceous pollen not exceeding 25-30%. The weakly magnetised regressive facies are characterised by steppe palynocomplexes dominated by herbaceous pollen (Sedaycin *et al.* 1987).

This indicates that the petromagnetic characteristics of the rocks, may mirror the climatic changes: alternations of relatively humid warm and cool arid periods.

The physical-mineralogic foundation of such interrelations are quite evident. In the moments of climatic optima, favourable conditions are created for production, drift and accumulation of substantial masses of plant organic matter; the burial of this matter gives rise to reducing conditions necessary to form authigenic sulphides in natural silts. As it follows from the available data, the transgressive phases in the Actchagylian and Apsheronian basins coincided with climatic optima.

The problem of correlations between climatic events and sedimenration settings in the Plio-Pleistocene basins of the eastern Para-Tethys form a long standing discussion. A wide range of ideas has been presented; various authors arrive at diametrically opposite conclusions on the basis of virtually similar data. Yakhimovich *et al.* (1985) correlate the Palaeo-Caspian transgressive stages with the Plio-Pleistocene climatic optima and the regressive stages with the periods of cooling in the Volga-Ural Region. Zubakov (1990), on the contrary, asserted that the Pliocene regressions of the Caspian Sea are related with the thermochrons, and the high stand stages – with cooling and aridisation in the Cis-Caspian Region.

Fedorov (1978, 1982), in his studies of the Pontic-Caspian palaeogeography, changed views more than once.

Petromagnetic data demonstrate, that the transgressive facies of elemental rhythms are associated with thermochrons, and the regressive ones with cryochrons. There is no support to correlate large transgressive cycles with climatic optima, because some information has been gained on multiple vegetation-community changes, and consequently, on climate oscillations throughout each of the Pliocene transgressions.

In the Cis-Caspian, Volga and Cis-Ural regions, the period of the maximum middle Actchagylian transgression coincides with up to six changes of climatic conditions recorded by corresponding alternations of plant communities. Not less than eight climatic oscillations are revealed in the Apsheronian time from palynological data: four of them in the early and middle Apsheronian and four at the end of the middle and in the late Apsheronian (Yakhimovich *et al.* 1985). On the whole, at least fourteen climatic rearrangements took place during the four transgressive-regressive cycles of the late Pliocene.

The origin of the great Caspian transgressions presents one of the major problems in the Pliocene-Pleistocene history of the Para-Tethys and its northern borders. The majority of the authors relate them with water-balance changes in the basin in response to climatic change (Fedorov 1978; Zubakov 1990). A number of publications refer to the combined effects of tectonic and Late Cainozoic climatic events (Vostryakov 1973; Nevesskaya *et al.* 1986).

One crucial aspect should be considered while discussing this problem. The Actchagylian Stage in the evolution of the Pontic-Caspian was accompanied by a major change in the outflow system of between the Para-Tethys basins. A sharp reduction of sublatitudinal water-transfer took place, and a stable system of gigantic meridional movements of water masses set up.

No events of such magnitude are possible without large structural rearrangements of the Earth crust, and the influence of the tectonic factor was probably decisive. Vostryakov (1973) paid particular importance to the regional neotectonic movements in territories of the Volga and northern Cis-Caspian regions, but fails to account for the Actchagylian transgression to western Turkmenia and the Aral Sea basin. It may be possible that the changes of transgressive-regressive cycles were controlled by the combinations of oscillatory motions of the southern Caspian deep-water part and the Russian Plate south-eastern periphery, the Peri-Caspian Depression included.

The dynamics of the Pliocene transgressions, exemplified by the middle Actchagylian, may be assessed as a first approximation magnetochronologically through correlation of regional palaeomagnetic columns. Trubikhin (1977) assigned the beginning of the middle Actchagylian transgression in Turkmenia to the middle of Gauss epoch - ~3 Ma (above Kaen episode). The northern limit of the middle Actchagyl sediments, corresponding to the end of Gauss epoch (~2.5 Ma), spreading is established in well 3 near the city of Saratov. Thus, during the 0.4-0.5 Ma – long interval, corresponding to the second half of Gauss epoch, the Actchagylian sea shore-line has shifted northwards for more than 1500 km, which corresponds to the average rate of 3 m per year.

CONCLUSION

Scalar magnetic characteristics of rocks reflect the conditions of the sedimentation; this allows to use petromagnetic data for palaeogeographic and geodynamic reconstructions. Sharp changes in sedimentary rock magnetisation serve as a direct indication for increased tectonic activity within source areas, resulting in new magnetic material. In the Late Neogene from the Black Sea region, a major petromagnetic boundary is associated with the Meotian/Pontian boundary.

An active input of magnetic material into the marine basin proceeded since the Late Pliocene, culminating at the end of the Pliocene. The Paleogene effusives of the Adjar-Trialet Ridge are known to be the main source for the south-eastern part of the Euxinic Basin; the Ridge is characterised by stable uplift for at least 5.4 Ma (since the start of Gilbert epoch to the present). Active uplift of the Main Ridge and, probably, the Talysh Mountains at the eastern end of the Caucasus began as late as at the end of Gilbert epoch and terminated in the early Gauss. The Mesozoic and Palaeogene effusives constituted the source of the magnetic material transported to the Balakhan Basin.

The transgressive-regressive cycles in the Euxinic and Caspian basins were significantly different in their magnitude. The Euxinic Basin did not change its outline notably during the whole of the Plio-Pleistocene.

The Euxinic Basin did not change its outline notably during the whole of the Pliocene, since the area extent of the incursions were rather limited. The Caspian transgressions, contrary to the Black Sea ones, resulted in the creation of vast basins.

The largest of them, the middle Actchagylian one, extended for more than 2000 km, from the southern margin of the Caspian Basin to the Kama River basin.

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